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ABSTRACT

From 1967 to 1971 over 80,000 juvenile Atlantic menhaden, *Brevoortia tyrannus*, were tagged from Florida to Massachusetts. Returns of the internal ferromagnetic body tags from the commercial menhaden fisheries indicate the juveniles migrate as far south as Florida in the fall and winter and then redistribute northward along the coast by size as age-I fish during the following spring and summer. Larger 1-year-old fish migrate north earlier and in greater numbers than small ones which remain in more southern waters where some are not available to the fisheries for part of the year. Some northward movement of age-I fish from the South Atlantic fishing area to Chesapeake Bay, evidently occurs through midsummer.

INTRODUCTION

Atlantic menhaden *Brevoortia tyrannus* are spawned in the ocean but spend their first summer in estuaries. From spotter-pilot observations, our own aerial observations of schooled fish in autumn, and samples of catches landed in the fishery, we know that juveniles are distributed from Florida to Maine and move out of the estuaries in autumn. We do not know where juveniles from particular estuaries go in the fall or where they spend the following summer as 1-year-old fish, although it has been shown that they are not caught north of New Jersey and are rarely caught north of Delaware Bay (Nicholson, 1971a). In order for us to predict recruitment to the commercial menhaden fisheries in Virginia, North Carolina, and Florida, which are highly dependent on catches of age-I fish, information about where juveniles from large estuarine areas occur the following year is needed (Kroger et al.¹).

To test the three generalized hypotheses proposed by Nicholson (1971b and 1972) we tagged juveniles in late summer and autumn from 1967 to 1971 and recovered tags from the commercial menhaden catches. The hypotheses were: (1) juveniles produced in the North and mid-Atlantic migrate into the South Atlantic in the fall, (2) juveniles from all areas

redistribute northward by size in the spring and the largest 1-year-old fish go farthest north, and (3) many of the smaller juveniles are not recruited to the fisheries at age-I.

METHODS

The juvenile fish were tagged by two different techniques from 1967 to 1971. In 1967-69 juveniles occurring in commercial purse seine catches were tagged with tags, $14.0 \times 3.0 \times 0.5$ mm, which were used in adult menhaden studies (Pristas, 1970). A total of 2,100 were tagged in Core Sound, N.C. in 1967 and 3,800 in 1968 and 21,700 in 1969 in Chesapeake Bay. In 1969-71 juvenile menhaden were sought in estuaries in early autumn, captured with a haul seine, and tagged with a numbered ferromagnetic tag, $7.0 \times 2.5 \times 0.4$ mm, designed especially for juveniles (Kroger and Dryfoos, 1972, and Kroger and Pristas²). In Rhode Island in 1969, 1,020 juveniles were tagged in one estuary. From Florida to Massachusetts 21,149 were tagged in 21 estuaries in 1970 and 31,664 in 27 estuaries in 1971.

Means and ranges of fork length of the juveniles were determined from samples of fish collected at the time of tagging. In this report we refer to juveniles less than 110 mm as "small" and those greater than 110 mm as "large."

¹ Kroger, R. L., A. L. Pacheco, and J. F. Guthrie. Evolution and critique of survey methods for estimating relative abundance of juvenile menhaden. Unpublished manuscript. National Marine Fisheries Service, Atlantic Estuarine Fisheries Center, Beaufort, N.C. 28516.

² Kroger, R. L. and P. J. Pristas. Movements of tagged juvenile menhaden in the Gulf of Mexico. Unpublished manuscript. National Marine Fisheries Service, Atlantic Estuarine Fisheries Center, Beaufort, N.C. 28516.

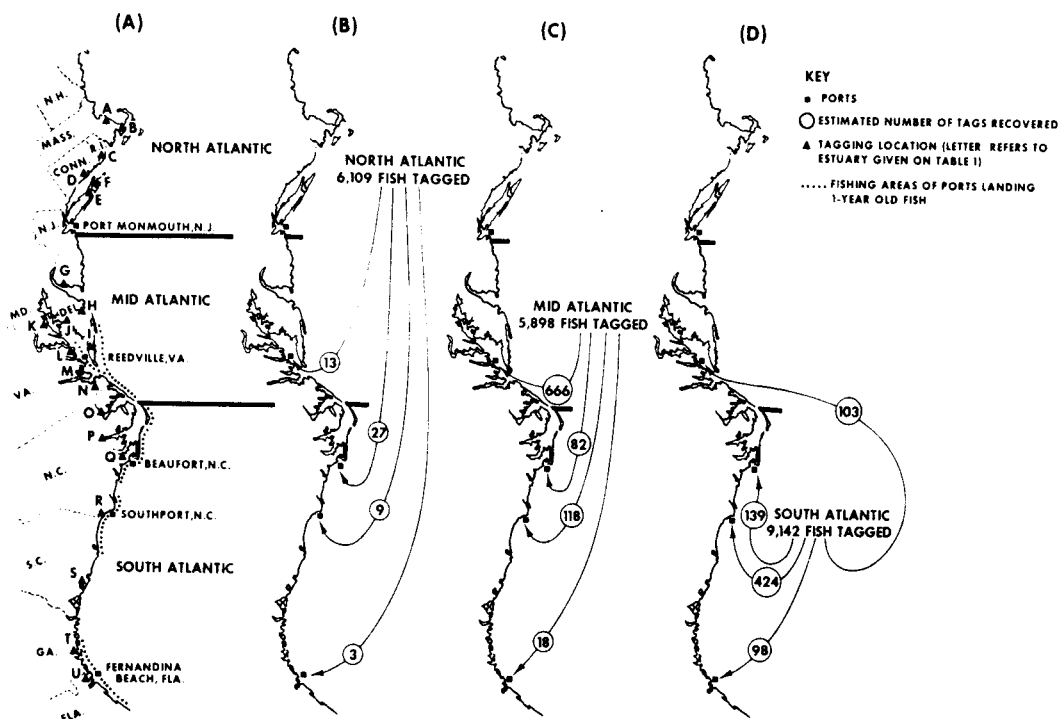


FIGURE 1.—Map A lists locations of menhaden ports, fishing areas and estuaries where juveniles were tagged (letters refer to locations listed on Table 1). Maps B, C and D list numbers of fish tagged in 1970 in the North, mid- and South Atlantic and the estimated number of tags recovered at each port in 1971.

Tags were recovered on magnets in reduction plants where the fish are processed into meal and oil. Because magnets collect only a portion of the tags which pass through the reduction process, a tag recovery efficiency rate was calculated for each plant. We placed 100 tagged fish into the catch each week and used the average percentage of tags recovered from all tests during the fishing season to calculate the number of tagged fish landed at each plant. Season plant efficiencies varied from 35 to 86% and the mean was 58%.

In this report tag returns have been treated as within-year recoveries, which occur from the time of release until the end of the fishing season, and first-year recoveries, which occur from April to the end of the fishing season the following year.

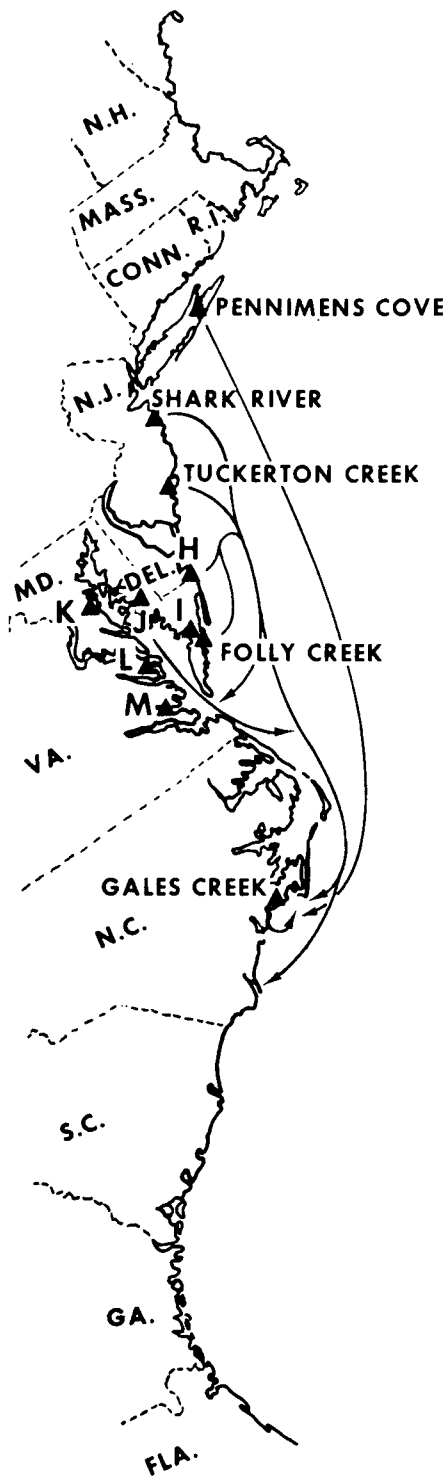
TAGGING AND RECOVERY AREAS

The Atlantic menhaden fishery has been divided into four geographical regions, the North Atlantic, Middle Atlantic, Chesapeake

Bay and South Atlantic, and the North Carolina fall fishery which occurs at Beaufort, N.C. from November to January (June and Reintjes, 1959). Except for combining the Middle Atlantic and Chesapeake Bay into a single release area called the mid-Atlantic region, we have retained these divisions in the analyses (Fig. 1). Purse seining usually begins in late April in Florida, early May in North Carolina, and late May in Chesapeake Bay. It usually ends by early October in Florida and at Southport, N.C., late December or mid-January at Beaufort, N.C. and mid-November in Chesapeake Bay. During the time we have been tagging juveniles, nearly all of the age-I fish caught have been landed at Chesapeake Bay and South Atlantic plants whose fishing areas never overlap (Nicholson, 1971a).

SOUTHWARD MIGRATION

The hypothesis that juveniles from mid- and North Atlantic estuaries move to areas south



of Cape Hatteras, N.C. in the fall of the year is supported by both within- and first-year recoveries of juveniles tagged in the mid- and North Atlantic. Small juveniles tagged in Rhode Island in October 1969 were captured in January 1970 in the North Carolina fall fishery (Kroger, Dryfoos and Huntsman, 1971). Small juveniles tagged in Pennimems Cove, N.Y. in September 1971 were recovered in mid-December 1971 at Beaufort, N.C. (Fig. 2). Fish tagged in Rhode Island in 1969 were also landed at Beaufort and Southport, N.C. and Fernandina Beach, Fla. in the summer of 1970. Large juveniles tagged in New York and small juveniles tagged in Rhode Island in 1970 were recovered in the South Atlantic in 1971 (Fig. 1, Table 1).

A total of 227 and 344 juveniles tagged with adult tags in Chesapeake Bay in 1968 and 1969 were recovered during the year of release in the North Carolina fall fishery. Juveniles released in 1970 in mid-Atlantic estuaries began occurring in the catches landed at Chesapeake Bay plants soon after they had been tagged and were recovered in the South Atlantic in 1971 (Table 1). Of the juveniles released in 1971 in five estuaries in Chesapeake Bay and four estuaries along the Coast from Accomac, Va. to Asbury Park, N.J., 77 were landed at Chesapeake Bay plants in October and November when they left the estuaries, and 61 at Beaufort, N.C. in mid-December when they occurred in large schools between Beaufort and Wilmington, N.C. Tags recovered from the first catches landed at Fernandina Beach, Fla. in early May 1972 included 16 from these releases (Fig. 2).

Juveniles tagged in the South Atlantic also showed a southward movement. First-year recoveries from juveniles tagged in Core Sound, N.C. in 1967, in Hancock and Calabash Creeks, N.C., in Store Creek, S.C., and Sapelo River, Ga. in 1970 were landed at Fernandina Beach, Fla. None of these fish were recovered during the year of release at Southport, N.C. or Fernandina Beach, Fla. because fishing

FIGURE 2.—Within-year movement of juvenile menhaden tagged in estuaries in September and October 1970. Only estuaries not tagged in during 1970 are labeled; refer to Table 1 for other locations.

TABLE 1.—Number of juvenile Atlantic menhaden tagged in 1970 and estimated number recovered through 1971 (tag returns have been adjusted for plant efficiencies)

Estuarine release area and code letter to Figure 1			Number tagged	Mean fork length (mm)	Tags recovered							
					Area						Total	
					Chesapeake Bay	Beaufort, N.C.		South- port, N.C. 1971	Fernan- dina Beach, Fla. 1971			
						1970	1971			Summer 1971		Fall 1971
										Number	Percent	
Green Harbor, MA	A	1,200	74	0	0	0	0	0	0	0	0	0.0
Childs River, MA	B	1,400	73	0	0	0	0	0	0	0	0	0.0
Winnapaug Pond, RI	C	1,200	87	0	0	0	0	0	0	0	0	0.0
Old Ferry Creek, CT	D	48	100	0	0	0	5	1	0	6	0.5	
Peconic River, NY	E	1,000	65	0	0	0	0	0	0	0	0	0.0
Great Peconic Bay, NY	F	1,261	120	0	0	0	0	0	0	0	0	0.0
Stow Creek, NJ	G	347	134	0	13	9	13	8	3	46	3.3	
White Creek, DE	H	900	133	0	20	2	0	11	0	33	9.5	
Onancock Creek, VA	I	1,000	153	153	114	4	2	3	0	164	18.2	
Choptank River, MD	J	351	136	11	51	2	0	7	0	276	27.6	
Broad Creek, MD	K	1,000	130	7	97	15	8	25	3	71	20.2	
Ball Creek, VA	L	1,200	126	79	182	7	3	14	3	155	15.5	
Felgate Creek, VA	M	100	124	9	26	1	0	3	0	288	24.0	
Nansemond River, VA	N	1,000	121	0	61	7	10	3	0	39	39.0	
Chowan River, NC	O	1,200	82	0	0	0	0	30	11	119	11.9	
Pamlico River, NC	P	1,600	72	0	0	0	0	0	0	0	0.0	
Hancock Creek, NC	Q	842	77	0	0	0	0	0	0	0	0.0	
Calabash Creek, NC	R	1,400	86	0	0	0	2 ¹	6	7	21	2.2	
Store Creek, SC	S	1,400	131	0	58	58	4	34	18	54	3.9	
Sapelo River, GA	T	1,400	126	0	45	66	7	190	18	328	23.4	
Lanceford Creek, FL	U	1,200	72	0	0	0	0	177	42	337	24.1	
Total		21,149						17	13	30		
											1,967	9.3

¹ Six tagged fish were also landed during the fall of 1970.

ceases in these areas before juveniles leave the estuaries.

NORTHWARD REDISTRIBUTION OF AGE-I MENHADEN BY SIZE

The hypothesis that age-I juveniles redistribute northward in the spring by size, with larger fish going farthest north, is supported by tag returns from North and mid-Atlantic releases. Small juveniles released in Rhode Island in 1969 and 1970 were recovered the following year only in the South Atlantic. Large juveniles tagged in Great Peconic Bay, N.Y. in 1970, however, were recovered in Chesapeake Bay as well as in the South Atlantic, implying that larger juveniles have a greater tendency to migrate farther north as age-I fish than do smaller juveniles. Although some of the large juveniles released in the mid-Atlantic in 1970 were recovered in the North Carolina and Florida fisheries in 1971, three times as many were recovered at Chesapeake Bay plants (Table 1). Very large juveniles, 153 mm average length, tagged in Onancock Creek, Va., had the lowest recovery rate in the South Atlantic, while slightly smaller juveniles, 121 mm average length, tagged in Nansemond River, Va. had the

highest recovery rate. This suggests that the redistribution pattern may be discernable between groups of fish averaging only a 32-mm length difference. Ninety-six percent of the first-year recoveries of other very large juveniles tagged in 1968 and 1969 in Chesapeake Bay were landed at Chesapeake Bay plants. Two percent (23 fish) were recovered as far north as Port Monmouth, N.J., and 2% were landed as far south as Southport, N.C.

Tag returns from small juveniles released in the South Atlantic also support the hypothesis that age-I menhaden redistribute by size. Small juveniles released in Hancock and Calabash Creeks, N.C. and Lanceford Creek, Fla. in September 1970 were recovered only in the South Atlantic in 1971. Ninety-five percent of the recoveries from small juveniles tagged in Core Sound, N.C. in December 1967 were recovered in the South Atlantic, while only 5%, possibly the larger fish in the group, were recovered in Chesapeake Bay.

Returns suggest that large juveniles in the South Atlantic may have a tendency to remain in the South Atlantic rather than moving north of Cape Hatteras as do similar sized juveniles tagged in the mid-Atlantic. Eighty-five percent of the fish tagged in Sapelo River,

Ga. and Store Creek, S.C. in 1970 were recovered in the South Atlantic in 1971 (Table 1). If the largest of the fish tagged constituted the 15% recovered in Chesapeake Bay, the hypothesis that the larger fish go farther north would be supported. But since individual fish were not measured, we do not have this information.

Larger age-I menhaden migrated north earlier than the smaller ones. Juveniles, 153 mm average length, tagged in Onancock Creek, Va. in 1970 were recovered in early May in pound net catches in Chesapeake Bay. Large juveniles tagged in Chesapeake Bay in 1968 and 1969 also were recovered in May the following year in pound net catches.

Northward movement of age-I fish evidently continues through July rather than ending by June as hypothesized by Nicholson (1971b). Of the tagged juveniles released in eight mid-Atlantic tagging locations in 1970 and recovered in Chesapeake Bay in 1971, fish from three releases were not caught until early July, and fish from three other releases were not recovered until after 15 June. Only fish from two releases were caught by 15 June, and these were from groups having the largest mean lengths. Fish tagged in Store Creek, S.C. and Sapelo River, Ga. in 1970 were recovered in early May 1971 in the South Atlantic but were not recovered in Chesapeake Bay until July. Those released in Great Peconic Bay, N.Y. were recovered in May and June in the South Atlantic but were not recovered in Chesapeake Bay until August, indicating that many of the 1-year-olds either had not reached Chesapeake Bay or had not entered the fishery by mid-summer in 1971.

NONRECRUITMENT OF SMALL AGE-I FISH

The hypothesis that small juveniles are not fully recruited to the fisheries at age-I (Nicholson, 1972) is supported by tag returns from releases in the North and South Atlantic. Generally, the small tagged fish were recovered later in the following season than the larger fish. Although some of the small juveniles tagged in Rhode Island in 1969 were caught in June in an estuary near Beaufort, N.C., none were recovered in typical commercial menhaden fishing areas until July and Sep-

tember at Fernandina Beach, Fla. and Southport, N.C. Small fish tagged in 1970 in Rhode Island also were not recovered until late in the 1971 season at Beaufort and Southport, N.C. Most of the small juveniles tagged in 1970 in Hancock and Calabash Creeks, N.C. and recovered in the South Atlantic in 1971 were not caught until August, suggesting non-availability of small age-I fish to the fisheries during the first half of the summer. Small fish released in Lanceford Creek, Fla., however, were recovered in small numbers from May to August at Fernandina Beach, Fla. and from late June to October at Southport, N.C. In contrast, tagged juveniles from groups averaging 110 mm or larger were caught in large numbers throughout most of the season in Chesapeake Bay and the South Atlantic. We should point out that the percentage of tags returned does not necessarily indicate degrees of recruitment because more of the smaller juveniles may die of tagging mortality than larger juveniles as outlined below.

MORTALITY OF SMALL TAGGED JUVENILE MENHADEN

We think tagged fish from four North Atlantic and two South Atlantic release locations in 1970 were not recovered because of predation (Table 1). Chub mackerel, *Scomber colias*, at Green Harbor, Mass. and bluefish, *Pomatomus saltatrix*, in Peconic River, N.Y. were observed eating many of the tagged fish as we released them (Kroger and Guthrie³). We examined three stomachs from chub mackerel at Green Harbor, Mass. and found seven juvenile menhaden, two of which we had just tagged. In Childs River, Mass., commercial eel fishermen who collected several bushels of juvenile menhaden from the specific release location each day for eel bait may have caught most of the tagged fish before they left the estuary. In Chowan River, N.C., the large striped bass, *Morone saxatilis*, population, which feeds mostly on juvenile menhaden during much of the year (Charles

³ Kroger, R. L. and J. F. Guthrie. Effects of predators on juvenile menhaden in clear water. Unpublished manuscript. National Marine Fisheries Service, Atlantic Estuarine Fisheries Center, Beaufort, N.C. 28516.

Manooch, personal communication), may have reduced the number of survivors. Similar predation may also have occurred in the Pamlico River. If any of these small juveniles survived, some should be recaptured in the 1972 fishing season as age-II fish.

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